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EXPERIMENTAL AND THEORETICAL STUDIES OF AUTOIGNITION AND BURNING SPEED OF JP-8 AND DF-2
Grant No.: W911NF0510051

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Summary

The capabilities of the combustion laboratory at Northeastern University have increased tremendously over the past year. The construction of the new experimental apparatus has allowed for much greater productivity. The addition of thick windows for the cylindrical vessel has allowed the lab to undertake testing at higher pressures and temperatures. Follow up the previous reports; we have used our modified burning model to measure laminar burning speed of JP-8, 21% O_2 and 79% He at wide range of temperature, pressure and equivalence ratio.

Technical Discussion

1. Review of the Burning Model Using Pressure Method

More detail of the burning model has been presented in the previous reports. Here for the sake of review we bring up the general equations. The total volume of the gas in the combustion chamber is

$$V_i = V_c - V_e = V_b + V_u \qquad 1.1$$

The energy conservation equation is

$$E_i - Q_e - Q_w - Q_r = E_b + E_u \qquad 1.2$$

where E is the initial energy of the unburned gas, Q_w is the conduction heat loss to the wall, Q_e is the conduction heat loss to the electrodes, Q_r is the heat loss due to radiation from the burned gas.

The radiation heat loss from the burned gas was calculated using

$$Q_r = \int_0^t \dot{Q}_r(t') dt' = 4\alpha_p V_b \sigma T_b^4 \qquad 1.3$$

where α_p is the Planck mean absorption coefficient and σ is the Stefan- Boltzman constant.

Burning speed may be defined

$$S_b = \dot{m}_b / \rho_u A_b = m\dot{x} / \rho_u A_b \qquad 1.4$$

where A_b is the area of a sphere having a volume equal to that of the burned gas. This expression is valid for smooth, cracked, or wrinkled flames of any shape.

2. Laminar Burning Speed Measurements

In the previous reports we have presented our experimental results for the burning speeds of JP-8 and air over a wide range of temperature, pressure and equivalence ratio. We have

facilitated our cylindrical vessel with heating elements, thicker windows and more elaborate data acquisition system. Figure 1 shows the flame shadowgraph images of stoichiometric JP-8 air at initial pressure of 1 atm and temperature of 450 k. It can be seen that flame turns cellular and is not laminar at the end stages of the combustion as pressure and temperature are high.
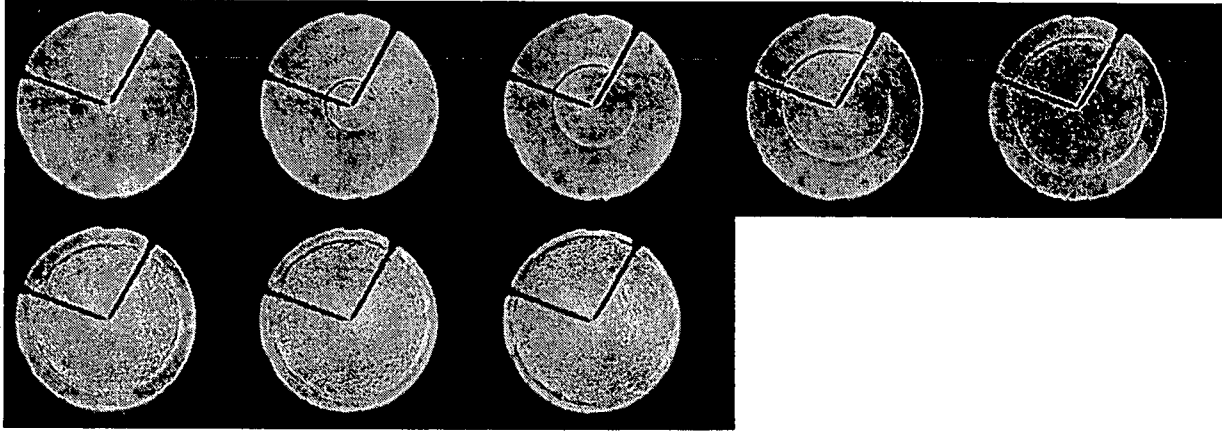

Figure 1: Shadowgraph images of premixed JP-8 and air ignited at equivalence ratio of 1, initial pressure of 1 atm and temperature of 450 K. Step size is 4 ms.

It has long been known that the replacement of the Nitrogen as the diluent with Helium will allow for the flame to become laminar. The Lewis number for Helium is less than that of Nitrogen, which decreases the tendency towards the formation of thermal diffusive cellular structures in the flame. It was decided to replace the Nitrogen with an equal percentage of helium. As it shown in Figures 2-4, this addition did make the flame laminar over a range of initial pressures and equivalence ratios.
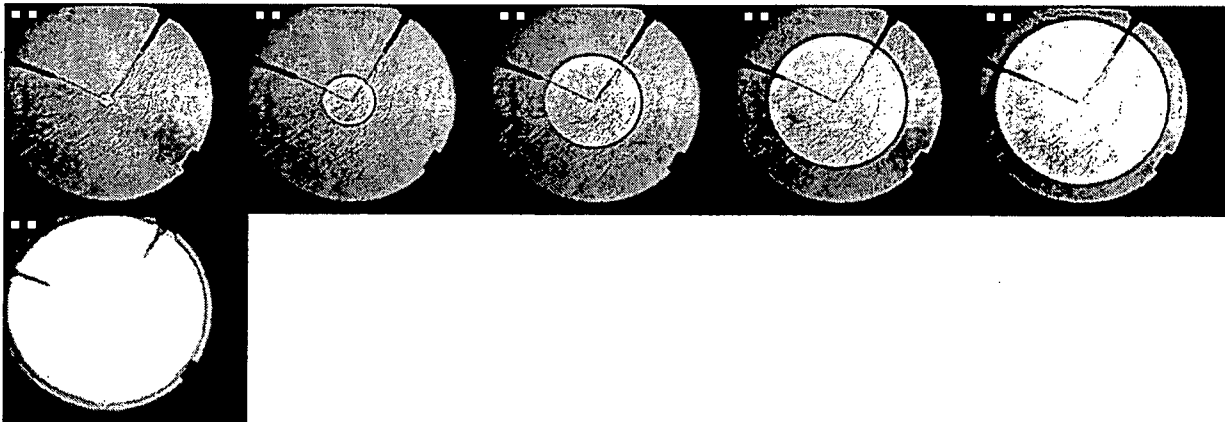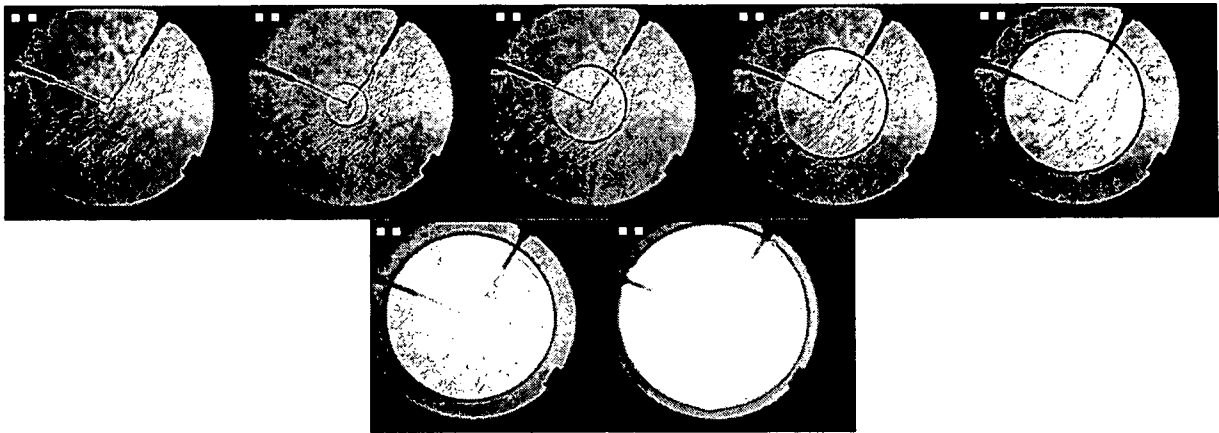

Figure 2: Shadowgraph images of premixed JP-8, 21% O_2 and 79% He ignited at equivalence ratio of 1, initial pressure of 1 atm and temperature of 473 K. Step size is 4 ms.
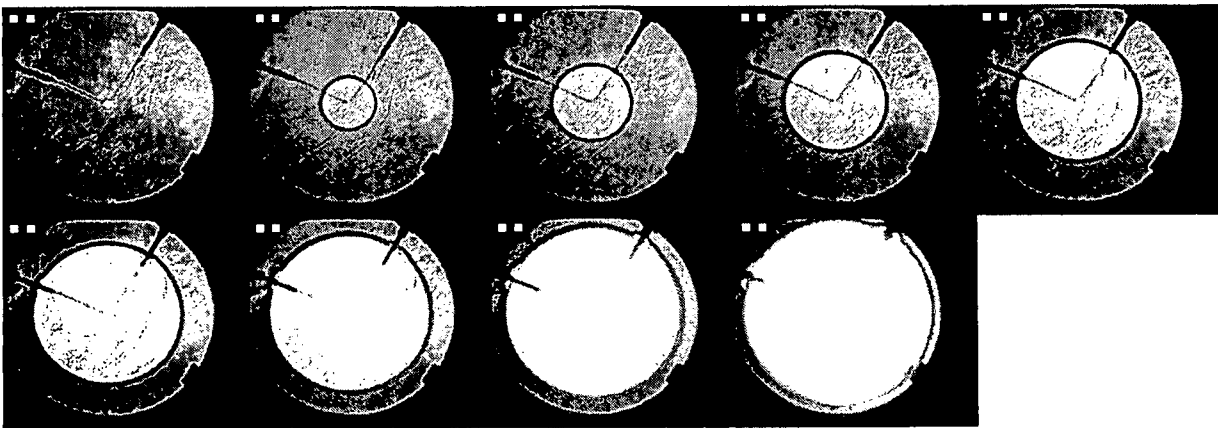
After this observation, laminar burning speed of JP-8 has been measured using the pressure method and our burning model over $1 < P < 13 atm$, $450 < T < 750 K$ and $0.8 < \phi < 1$. The results are shown in Figures 6-7.

36

Figure 3: Shadowgraph images of premixed JP-8, 21% O_2 and 79% He ignited at equivalence ratio of 0.8, initial pressure of 1 atm and temperature of 473 K. Step size is 4 ms.

Figure 4: Shadowgraph images of premixed JP-8, 21% O_2 and 79% He ignited at equivalence ratio of 1, initial pressure of 2 atm and temperature of 473 K. Step size is 4 ms.
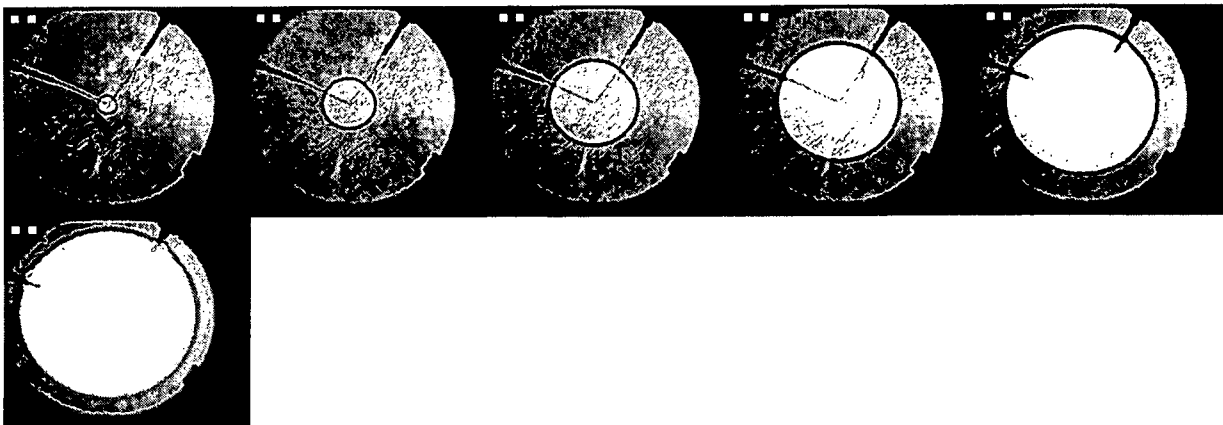

Figure 5: Shadowgraph images of premixed JP-8, 21% O_2 and 79% He ignited at equivalence ratio of 0.8, initial

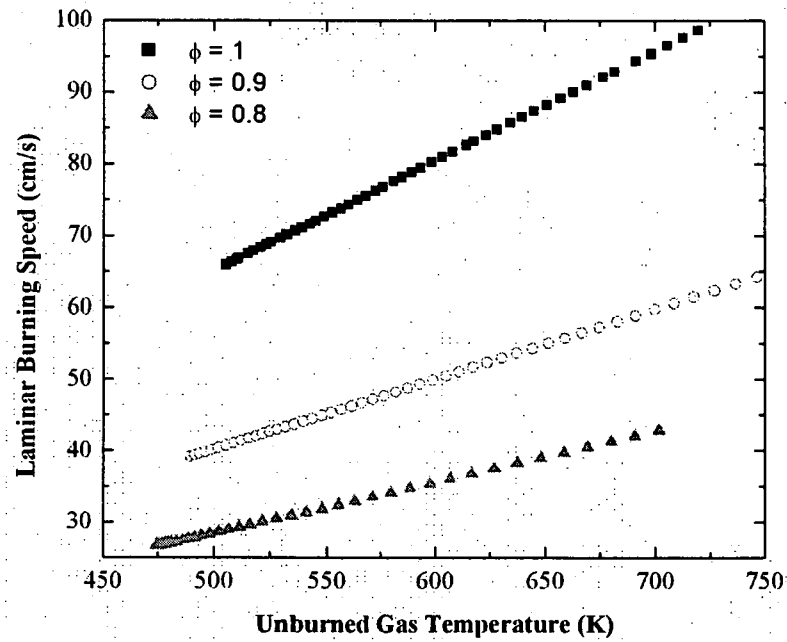pressure of 2 atm and temperature of 473 K. Step size is 4 ms.

Figure 6: Laminar Burning Speed of JP-8, O2 and He. P_i = 1 atm, T_i = 473 K
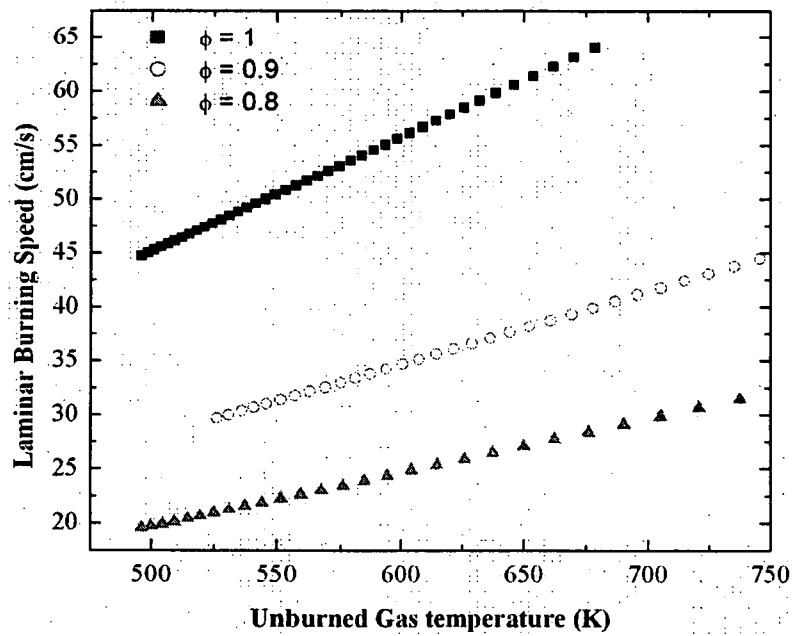

Figure 7: Laminar Burning Speed of JP-8, O2 and He. P_i = 2 atm, T_i = 473 K